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# Exploring the Impact of Time and Gender on MMSE Scores

## 1. Introduction

This research investigates the influence of time and gender on cognitive performance as measured by the Mini-Mental State Examination (MMSE). The project is anchored on the premise that cognitive dynamics, as captured through MMSE scores, may exhibit variations across multiple time points (visits) and differ between genders. This longitudinal study utilizes a within-subjects design to track changes over three visits, thereby assessing the trajectory of cognitive function over time for each participant. Additionally, it incorporates a between-subjects factor, gender, to explore potential differences in cognitive trajectories between male and female participants. Through mixed-effects ANOVA, the study aims to uncover whether the interaction between time (visits) and gender significantly affects MMSE scores. This approach allows for a fine understanding of cognitive decline or stability in the context of dementia, providing insights into how gender may modulate these changes over time. The ultimate goal is to elucidate the patterns of cognitive performance across different time points and between genders, shedding light on the complexities of cognitive aging and the progression of dementia. Hence, out dependent variable is the MMSE, our between subjects variables is gender, and out within subjects variable is visits/time. Our concrete research question is:

Is any change in the MMSE score is the result of the interaction between the gender and time passed?

## 2. Data Cleaning and Data Wrangling/ Feature Engineering

After the loading and observation of the data, we look at the amount of zero and null values for each entry. After calling the function, we see that there are is only one entry in the relevant column set of MMSE, F/M, Visit, Subject ID where one of these columns is empty (MMSE in this case). Therefore, to investigate further, we display it. Then we delete it. To answer our research question, only the forementioned columns are needed. Therefore we can simply delete the remaining columns which are irrelevant to our study. Now, for the next step, in order to observe time fairly, we need to observe the number of entries(which correspond to the number of visits logically) for each subject, which is what we compute next. We see that there are 143 subjects with 2 visits and 7 subjects with a single visit. Since the amount of visits, which are our time interval/nodes, need to be equal for all of the subjects irrespective of their genders for us to compare, and since we have a large enough subject pool for only the group case where there have been two visits for each subject, we simply delete those 7 ids that have visited once. Then we check again to make sure that they are deleted and see that now the only remaining subjects are the 143 subjects that have 2 visits each. Now, we are ready to move onto the exploratory data analysis.

## 3. Exploratory data Analysis (EDA)

Now, for the purposes of answering the research question, it is a good idea to graph the MMSE scores for each gender in the two visits (as a side note, as explained in the dataset on kaggle the visits are all roughly one years apart for each subject) to get a sense of the relations and make a prediction for answering the research question before moving onto the tests.

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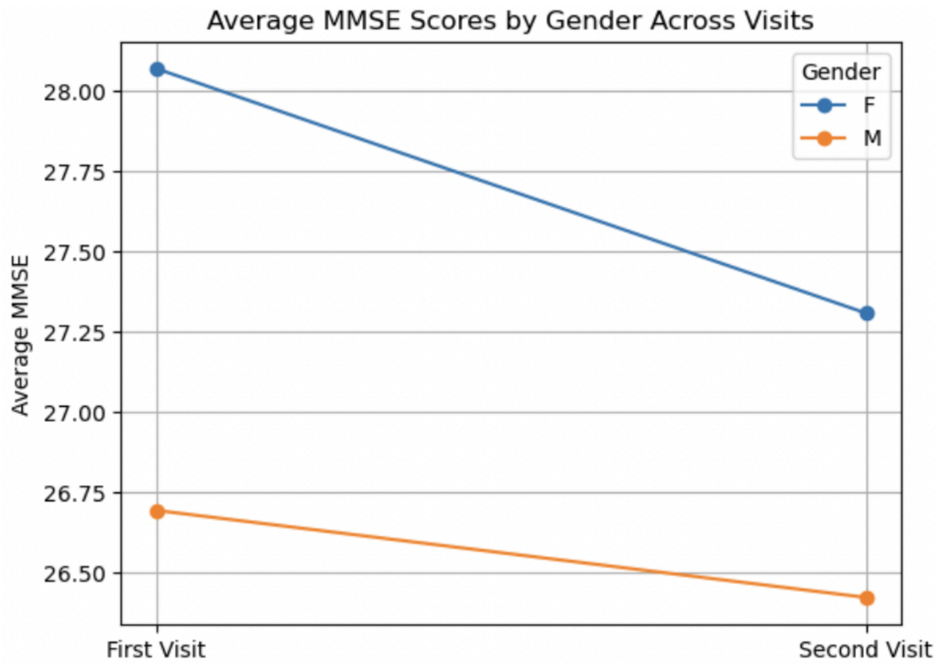


FIGURE 1: Average MMSE Score vs Visits (Lines Grouped by Gender)

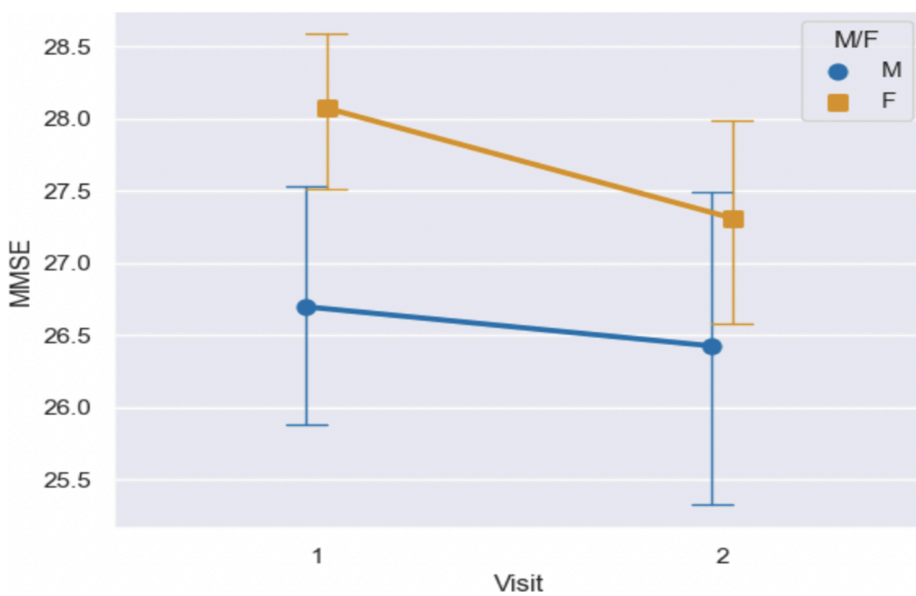


FIGURE 2: Average MMSE Score vs Visits (Lines Grouped by Gender)

As seen from both of the graphs above, the results indeed suggest that there is a significant effect on the change in the MMSE score caused by the interaction between the gender and the time passed. The female subjects clearly seem to have a higher overall score in both visit times and the second visit times for both genders have a smaller MSSE than the first visits, though this decrease is more present in the females, which might be because it might be harder for the treatments to decrease the already lower scores for males. It is also a good idea to perform the summary statistics of all 4 groups to see if this observation is supported further. The results are in the below figure:

| | Min | Max | Mean | 25th % | Median | 75th % | IQR |
|---|---|---|---|---|---|---|---|
| Female Visit 1 | 19 | 30 | 28.07 | 27 | 29 | 30 | 3 |
| Male Visit 1 | 17 | 30 | 26.69 | 25 | 28 | 29 | 4 |
| Female Visit 2 | 15 | 30 | 27.31 | 27 | 28.5 | 30 | 3 |
| Male Visit 2 | 15 | 30 | 26.42 | 25 | 28 | 29 | 4 |

FIGURE 3: Summary Statistics of each of the Four Groups

All 4 of these summary statistics for the groups further back up the claims above. This can be seen by comparing the means, medians, and the percentiles.

## 4. Performing the Mixed-Effect ANOVA

Now it is time to perform the previously talked about mixed-effects ANOVA. Below are the results:

| Source | SS | DF1 | DF2 | MS | F | p-unc | np2 | eps |
|---|---|---|---|---|---|---|---|---|
| M/F | 88.689 | 1 | 141 | 88.689 | 4.321 | 0.039 | 0.030 | nan |
| Visit | 22.378 | 1 | 141 | 22.378 | 8.610 | 0.004 | 0.058 | 1 |
| Interaction | 4.173 | 1 | 141 | 4.173 | 1.606 | 0.207 | 0.011 | nan |

FIGURE 4: Mixed-Effect ANOVA Results

The ANOVA results indicate a significant main effect of visit time on MMSE scores ($p = 0.004$), demonstrating that MMSE scores change over time. This finding confirms our initial hypothesis that cognitive performance, as measured by the MMSE, varies across visits. Furthermore, there is a significant main effect of gender ($p = 0.039$), suggesting that MMSE scores also differ between genders.However, the interaction effect between visit time and gender is not statistically significant ($p = 0.207$). This suggests that while both time and gender independently affect MMSE scores, their interaction does not significantly influence the outcomes. This finding is crucial for interpreting the complexity of cognitive changes over time and across genders. It implies that both factors should be considered separately when assessing cognitive performance trends. Now, given the significant main effects observed in the ANOVA, post hoc tests were conducted to further explore the differences between groups. The purpose of these tests is to understand more deeply how MMSE scores vary by visit and gender and to identify specific group differences after detecting a significant overall effect.

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| Contrast | Visit | A | B | Paired | Parametric | T | dof | alternative | p-unc | BF10 | hedges |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Visit | - | 1 | 2 | True | True | 2.928 | 142 | two-sided | 0.004 | 5.530 | 0.162 |
| M/F | - | F | M | False | True | 1.990 | 104.517 | two-sided | 0.049 | 1.098 | 0.351 |
| Visit * M/F | 1 | F | M | False | True | 2.633 | 104.908 | two-sided | 0.010 | 4.138 | 0.464 |
| Visit * M/F | 2 | F | M | False | True | 1.319 | 106.117 | two-sided | 0.190 | 0.402 | 0.232 |

FIGURE 5: Post-Hoc Test Results

The pairwise comparisons reveal significant differences between the first and second visits ($p = 0.004$), underscoring the temporal decline in MMSE scores regardless of gender. Additionally, there is a borderline significant difference between genders, with females showing a trend towards higher MMSE scores than males ($p = 0.049$). Notably, the interaction contrast between visit and gender for the first visit shows a significant difference ($p = 0.010$), suggesting that the decline in MMSE scores from the first to the second visit may differ by gender. All of these takeaways further backup the initial claims. After this, to check for the assumptions of the ANOVA, we perform a Mauchly's test of sphericity, which assesses the assumption that the variances of the differences between conditions are equal. We ended up with a value of 1, suggesting that the assumption of sphericity is met for our within-subjects variable (visits/time). Then to check the normality assumption, the following results were produced:

| Visit | W | pval | normal |
|---|---|---|---|
| 1 | 0.792 | <0.001 | False |
| 2 | 0.761 | <0.001 | False |

FIGURE 6: Normality Results

The results suggest that the normality assumption is not met for the MMSE scores across visits ($p < 0.05$). Therefore, we should take the results of the test with a pinch of salt. Now lastly, to answer the question of determining the appropriate sample size for a theoretical experiment with power = 0.91, alpha = 0.05, and effect size = 0.7, we performed a TTestIndPower and graphed the results in the below figure.

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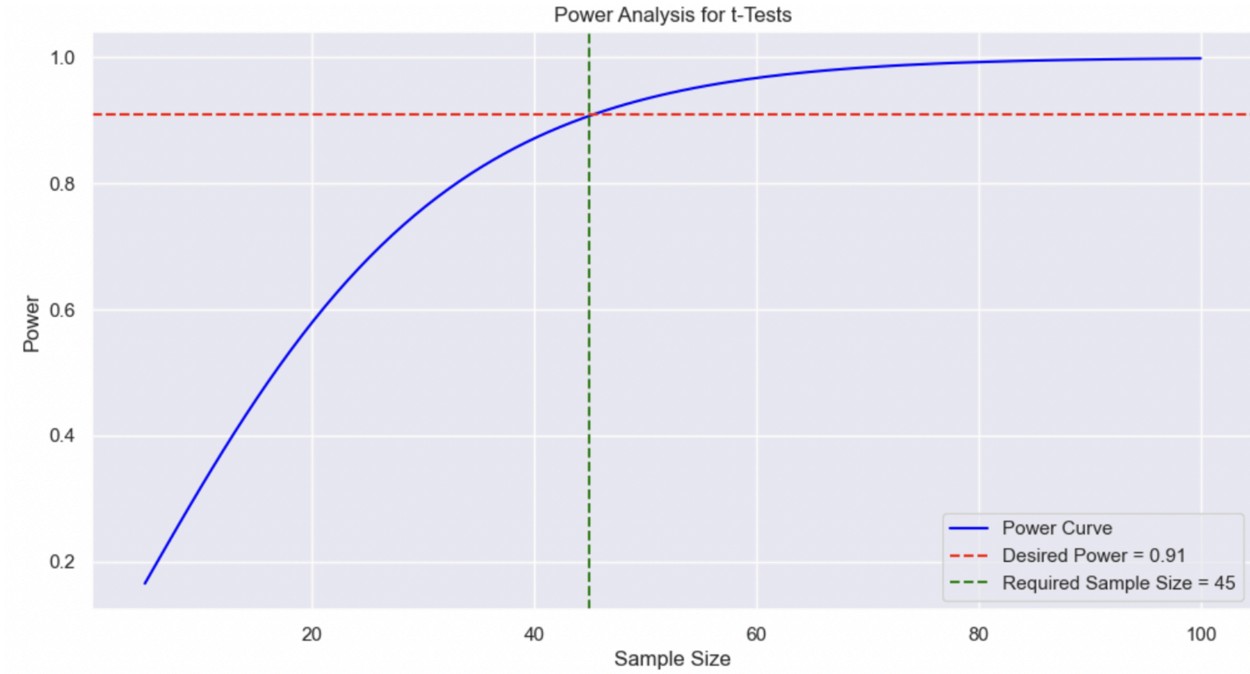


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Required sample size: 45
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FIGURE 7: Power Analysis for T-Tests Graph

The graph suggests that the appropriate sample size should be 45, which corresponds to the green dashed line. The red dashed line is the desired power level, which is 0.91.

## 5. Conclusion

This research aimed to understand how gender and time influence cognitive performance, measured by MMSE scores, across different visits. The findings revealed that time significantly affects cognitive performance, demonstrating a decline over visits, and that gender also plays a crucial role, with distinct differences between males and females. However, the interaction between time and gender did not show a significant impact on MMSE scores, indicating that while both factors are important, they independently affect cognitive performance rather than in conjunction. Despite limitations, such as the violation of the normality assumption, this study provides valuable insights into cognitive aging and highlights the importance of considering both time and gender in cognitive assessments. The research underscores the complexity of cognitive performance over time and suggests directions for future studies to further explore the dynamics of cognitive aging with a more nuanced approach.